ACCELERATED CEST MRI USING COMPRESSIVE SENSING AND MULTISHOT SPIRAL ACQUISITIONS

Sampada Bhave[1], Jinsuh Kim[1], Casey P Johnson[1], and Mathews Jacob[1]

[1]*University of Iowa, Iowa City, Iowa, United States*
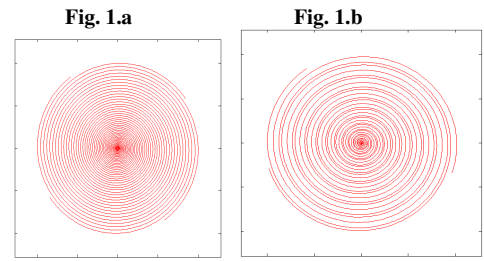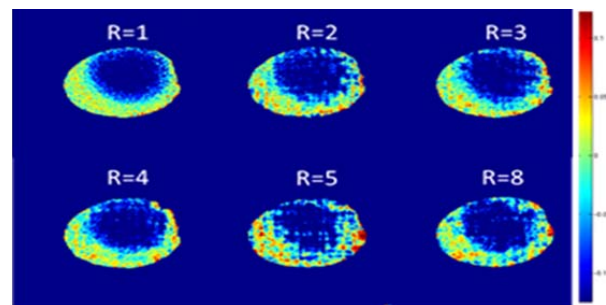
Fig. 1.a **Fig. 1.b**

Fig. 1. Spiral sampling trajectories corresponding to five fold (left) and eight fold (right) accelerations. These trajectories are obtained by skipping random spiral interleaves, resulting in reduced scan time.

Introduction: Chemical exchange dependent saturation transfer (CEST) has recently emerged as a new molecular contrast mechanism [1,2]. It relies on the reduction in the bulk water signal, resulting from the transfer of mobile protons between the metabolite of interest and water, when the metabolite is saturated using frequency selective saturation pulses. One of the challenges in CEST is the inherent sensitivity of frequency selective saturation to B0 inhomogeneities. In addition, magnetization transfer also affects the signal. To mitigate these problems, it is a common approach to perform frequency selective saturation at different frequency offsets (termed as z shifts), followed by line-fitting to quantify the CEST contrast [3,4]. Unfortunately, this approach increases the scan time considerably, especially when the data is acquired with high spatial resolution, thus restricting the clinical utility of this scheme. The main focus of this paper is to reduce the scan time in CEST imaging by using multi-shot variable density spiral acquisitions and compressive sensing. Since variable density spiral trajectories spend more time to acquire the central k-space regions, they are more SNR efficient than Cartesian schemes. We proposed to skip random spiral interleaves in different z planes to under-sample the data. The reconstruction of the entire dataset is posed as a spatially and spectrally regularized sparse optimization scheme.

Methods:
The recovery of the z-spectrum from undersampled data is posed as a spatially and spectrally regularized optimization scheme.

$$\mathbf{Y} = \arg\min_{\mathbf{Y}} \underbrace{\left\| A(\mathbf{Y}) - b \right\|_2^2}_{data\ consistency} + \underbrace{\lambda_1\, TV(\mathbf{Y})}_{spatial\ regularization} + \underbrace{\lambda_2 \left\| R(\mathbf{Y}) \right\|_1}_{spectral\ regularization} \;;$$

The total variation penalty is used for spatial regularization, while the l1 norm of the second degree spectral derivatives (denoted by $R(\mathbf{Y})$) is used as the spectral regularization term. The measured k space data is modeled as $\mathbf{b} = A(\mathbf{Y})$, where A is the Fourier sampling operator. In this work, the regularization parameters are selected based on the comparisons with the fully sampled acquisitions.

The CEST maps are computed using the six point method in [4]. We observe that the CEST maps corresponding to upto four fold acceleration results in minor degradation.

The data is acquired on a Siemens 3T Trio scanner. The fully sampled CEST data is acquired with a spatial matrix of 256x256 using a multishot variable density spiral trajectory with twenty interleaves. The readout was preceded by a pulsed RF train of pre-saturation irradiation (N=10, τ = 15 ms, 50% duty cycle, and ϕ = 180°). 42 different z shifts, uniformly distributed in a 10ppm range around the water frequency, are acquired. The scan time for acquiring the fully sampled data with 12 slices was 9 mins & 20 seconds. The reconstruction scheme is validated using retrospective down-sampling of the above data. Specifically, we retained a fraction of the interleaves and recovered the data using the proposed algorithm. For example, we retained four interleaves out of twenty for a five-fold acceleration. The sampling pattern for five-fold and eight-fold acceleration is shown in Fig 1.a and Fig 1.b respectively. To show effectiveness of this scheme, we acquired fully sampled CEST imaging data of egg phantom using a receive-only wrist coil.

Results:
The z spectra are compensated for the B0 variations post reconstruction. The z location corresponding to the maximum CEST contrast obtained by averaging a few z planes is displayed in Fig. 2.a. at different accelerations. The z-spectra averaged at two regions within the yolk and the white regions as a function of the accelerations are shown in Fig. 2.b. It is seen that the degradation as a function of acceleration is graceful.
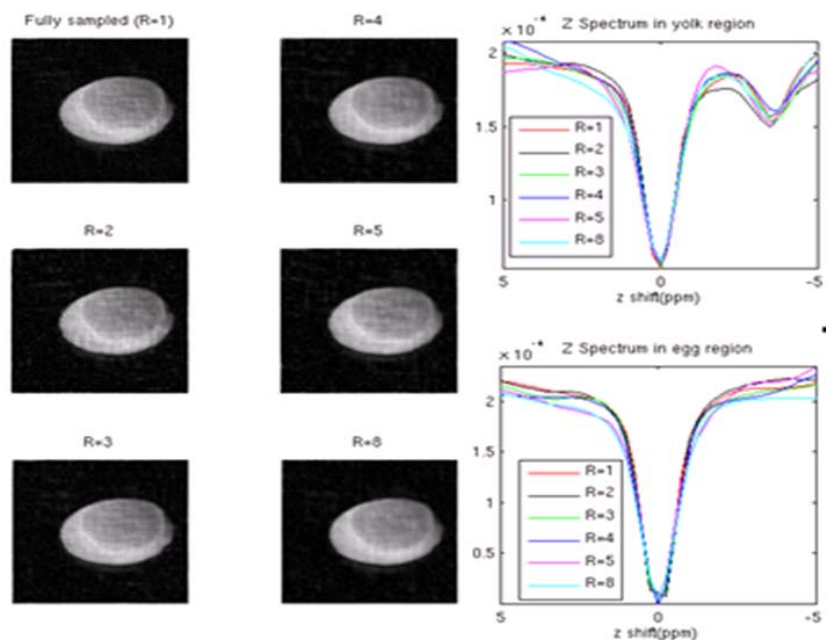

Fig.2 CEST acceleration: (a) shows the recovered CEST images at the z shift corresponding to maximum CEST contrast. (b) indicates the average of the z spectra at two regions of interest, one within the yolk (top) and the other within the white regions (bottom). Note that the degradation in the performance is graceful with acceleration.

It is observed that the degradation is graceful with acceleration; high accelerations can be obtained with minimal change in contrast. The quantitative CEST contrast images shown in Fig. 3. were derived from the recovered images using the six point algorithm [4] .

References: [1] Van Zijl et al. MRM'11, pp 927-48 [2] Zhe Sun et al, MRM'07. [3] Singh et al., MRM'12.[4] Zhou et. al. MRM, 2008. pp 842-849.